Estimation and Analysis of Carbon Emissions in Hubei Province Based on Energy Consumption

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Abstract

Hubei Province is at its 12th-Five Year Plan development stage with accelerating urbanization and new industrialization, which is surely driving the increase of energy consumption. Therefore, it is extremely important, in the broad background of calling for low carbon development from the world wide, that economic development is achieved and carbon emissions is reduced at the same time. This study was aimed to learn about the current situation of carbon emission from energy consumption in Hubei Province, China and give suggestions on related policies. In this study, industrial space was first classified into 3 groups of agricultural space, living and industrial-commercial space and transportation industrial space. Then, carbon emission from energy consumption was estimated using the method I of IPCC. The results showed that living and industrial-commercial land use imposed the biggest pressure on the environment in Hubei Province, followed by transportation industrial land use and then agricultural production land use. Although carbon emission from energy consumption is effectively controlled to some extent when economy is developed in Hubei Province, energy dependence has not been changed.

Keywords

Hubei Province; Industrial Space; Energy Consumption; Carbon Emission

Introduction

In the recent decades, severe overuse of natural resources by human beings, especially the fossil fuel combustion and land use changes, has resulted in the continuous going up of the CO_2 concentration in the atmosphere and consequently the global climate change. Studies indicated that increased CO_2 concentration in the atmosphere is the main causes of climate warming. And human activities such as large scale fossil fuel combustion and unsustainable land use change the carbon cycle, consequently leading to the increased CO_2.The rapid economic development in China generates a great demand on energy and results in world-leading CO_2 emission. Therefore, carbon emission reduction is especially important in China. Hubei Province is the pivot of the "Rise of Central China" strategy and the hub of national transportation. Since 2000, the total energy consumption in Hubei has surged greatly and taken up an ever larger (from 4% before 2000 to 4.66% in 2010) proportion of the national total consumption. Thus, Hubei takes up a key position in carbon emission reduction in China. Although research has been conducted on carbon emission from energy consumption in certain provinces and even cities and counties, areas involved are mainly from East China and the northwest region while the middle region is seldom involved. Also, few studies have coupled land use types in cities with industrial development. In this study, energy consumption during the 11 years from 2001-2011 in Hubei was analyzed and the effects of land use type on carbon emission were discussed in an attempt to help the development of low carbon economy in Hubei.

Study Area Outline and Data Source

Study Area Outline

Located in the middle of China and the middle reach of the Yangtze River, Hubei Province has been called "a thoroughfare to nine provinces", indicating its important position as a transportation junction. The area of Hubei ranked the 14th of all the provinces and autonomous regions in China. As a big agricultural

province, Hubei also invests a lot to develop industries. Therefore, it is a relatively developed province. In 2012, the total investment in fixed asset of the whole society in Hubei was 1650.417 billion Yuan, increasing by 27.6% compared with the last year. Industrial structure has been steadily upgraded. The value added of the primary, secondary, and tertiary industries was 284.877 billion Yuan, 1119.045 billion Yuan, and 821.094 billion Yuan, increasing by 4.7%, 13.2% and 10.8%, respectively. And the industrial structure was 12.8:50.3:36.9.

Data Source

Energy consumption data of 2002-2012 used in this study were mainly taken from the energy balance table of Hubei Province of the Energy Statistical Yearbook of China, and the GDP data from 2001-2011 of Hubei Province were taken from statistical yearbook of China.

Research Method and Carbon Emission Estimation

Calculation Method of Carbon Emission from Energy Consumption

The effects of land use type on carbon emission can be learned from the relationship between land use type and energy consumption of various industries. According to the land types defined by the current National Land Use Classification (for transition period) and the industries listed in the energy balance table for Hubei Province in the Energy Statistical Yearbook of China and current research, land use types were grouped based on classification of energy consumption industries (Table 1). As agriculture in China is not modernized enough to consume a lot of energy and other land use types (including special land use and unutilized land) are also associated with low energy consumption, agricultural land use and these land use types are grouped into one big type. The other two types are the major industries that consume energy. Therefore, they should be singled out for study so that analysis results are of more significance.

2006 IPCC Guidelines for National Greenhouse Gas Inventories introduces three methods for calculating carbon emission from energy consumption. In Methods I, actual carbon emission is estimated based on the amount of energy consumed, the net calorific value of energy, carbon emission coefficient and oxidation rate. Not many data are needed for this method and these data are easy to gather. Therefore, Method I is employed in this study to calculate carbon emission from energy consumption of various industrial terminals. To reflect the true direct carbon emission from various industries, only carbon emissions from carbon-containing energy sources were calculated while such energy sources as electric power were not.)The equation used for estimation is as follows:

$$C = \sum_{i=1}^{17} E_i \times NCV_i \times \delta_i \times OR_i$$

where C is carbon emission from fossil energy consumption ($\times 10^4$ t); Ei is the amount of the ith energy that is consumed ($\times 10^4$ t); NCVi is the average lower heating value (net calorific value) of the ith energy; δi is the carbon emission coefficient of the ith energy; ORi is the oxidation rate of the ith energy; i=1, 2, …, 17, or a total of 17 energy consumption types.

Carbon Emission Amount for Unit GDP

Total carbon emission from energy consumption is an index with absolute values and only when associated with indexes such as GDP, is it meaningful in horizontal comparison. Carbon emission amount for unit GDP is carbon intensity of energy consumption or the amount of carbon emitted over one unit of GDP. It is a major index for evaluating greenhouse gas emission and also an index for judging the contribution of developing countries to the mitigation of climate changes. It can also reflect carbon emission intensity. Theoretically, the smaller the carbon intensity of energy consumption, the better. Carbon intensity of energy consumption can indirectly tell us the rationality of the economic structure and the level of science and technology in economic development.

$$CI_t = C_t / GDP_t$$

where Ct is the carbon emission amount from energy consumption of year t ($\times 10^4$ t); GDPt is the regional GDP of year t ($\times 10^4$ Yuan); CIt is the carbon intensity of year t (kg/(10^4 Yuan)).

Results and Analyses

The total carbon emissions from 2001-2011 were obtained based on the energy consumption data from 2001-2011 in Hubei. As shown in Fig. 1, the total carbon emission dropped a little in 2003 and then continuously went up from 2761.84×10^4 t in 2001 to 1.3 times of 6370.36×10^4 t in 2011 with an average yearly

TABLE 1 LAND USE TYPES AND THEIR CORRESPONDING ENERGY CONSUMPTION

Industrial space	Land use classification	Energy-consuming industries
Agricultural space	Cultivated land Forest land Grassland Water area Water conservancy facilities Other land use (including special land use and unutilized land)	Agriculture, forestry, animal husbandry, fisheries, water conservancy, and others
Living and industrial-commercial space	Urban land use	Construction industry, wholesale, retail business, lodging, catering, living consumption
	Rural residential area	Rural living consumption
	Independent industry and mining	Industry
Transportation space	Transportation land use	Transportation, storage and post industry

TABLE 2 CALORIFIC VALUE, CARBON EMISSION COEFFICIENT AND OXIDATION RATE OF VARIOUS ENERGY TYPES

Energy type	Net colorific value (Average lower heating value) (TJ/(×10⁴ t), TJ/(×10⁸ m3))	Carbon emission coefficient (t C/TJ)	Oxidation rate
Raw coal	209.08	25.8	0.98
Cleaned coal	263.44	25.8	0.98
Other washed coal	94.09	25.8	0.98
Moulded coal	168	25.8	0.98
Coke	284.35	29.2	0.98
Coke oven gas	1735	12.1	0.995
Other gas	1827	12.1	0.995
Crude oil	418.16	20	0.99
Gasoline	430.7	20.2	0.99
Kerosene	430.7	19.6	0.99
Diesel	426.25	20.2	0.99
Fuel oil	418.16	21.1	0.99
Liquefied petroleum gas	501.79	17.2	0.995
Refinery dry gas	460.55	15.7	0.995
Natural gas	3893.1	15.3	0.995
Other petroleum product	401.9	20	0.99
Other coke chemicals	282	29.2	0.98

Note: (1) The data were compiled from the China Energy Statistical Yearbook of 2012, 2006 IPCC Guidelines for National Greenhouse Gas Inventories, and research results of Lu and Liu et al.;
(2) The net colorific values of coke oven gas, other gas and natural gas are in unit of TJ/(×108 m3), and the net colorific values for the other energy types are in TJ/(×104 t).

increasing rate of 10.39%. Carbon emission over unit GDP during 2001-2011 showed trends of steady decreasing in Hubei, indicating improvements in the economic rationality and the science and technology level during economic development in Hubei and that carbon emission was effectively controlled to some extent while economy developed.

As we can see from Fig. 2 that, the yearly increasing rate of total carbon emission had been continuously going up since 2008 and it had been over 10% since 2010and was even up to 17% in 2011. It suggests that although carbon emission over unit GDP had been effectively controlled, economic development still relies on energy consumption. It also indicates that economic development from 2001-2011 was at the cost of environmental quality and that sustainable development had not sunk in.

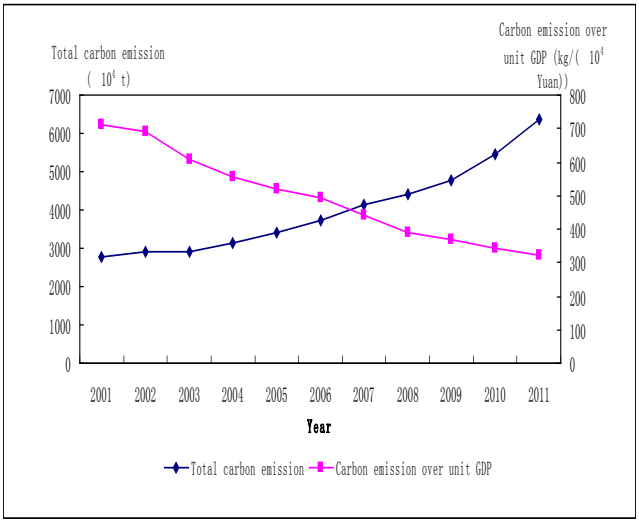

FIG. 1 CHANGES OF TOTAL CARBON EMISSION AND CARBON EMISSION OVER UNIT GDP IN HUBEI PROVINCE FROM 2001-2011

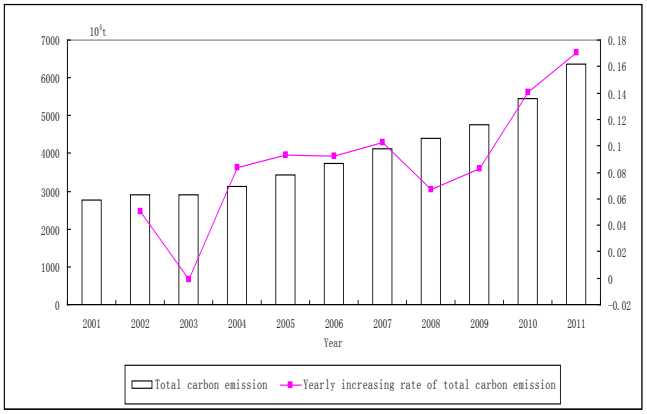

FIG. 2 CHANGES OF TOTAL CARBON EMISSION AND ITS YEARLY INCREASING RATE FROM 2001-2011 IN HUBEI PROVINCE

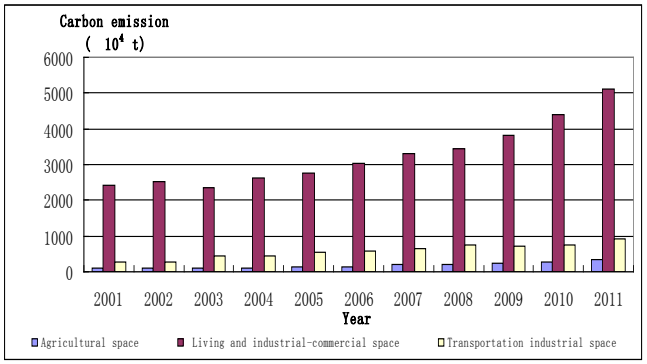

FIG. 3 CARBON EMISSION FROM VARIOUS LAND USE TYPES

We can see from Fig. 3 and Table 3 that carbon emission from lands used in agricultural space was relatively low and also took up a relatively small proportion in total carbon emission with the highest proportion of only 6% during the 11 years of 2001-2011. Carbon emission from the living and industrial-commercial space was far larger than those from the other two spaces and also increased relatively fast but its proportion in total carbon emission dropped a little. Carbon emission from the transportation industrial space displayed increasing trends as a whole and its proportion in total carbon emission had not changed much since 2003 with an average of 15%.

Conclusions and Policy Suggestions

Conclusions

1) The living and industrial-commercial land use imposes the greatest pressure on the environment in Hubei, followed by transportation land use, and agricultural production land use imposes the least. Therefore, reducing carbon emissions from the living and industrial-commercial space and the transportation industrial space is the key. However, at the same time, carbon emission reduction from the agricultural space cannot be neglected.

2) Carbon emission from energy consumption was effectively controlled to some extent in Hubei during economic development. However, economic development still relies on energy.

Related Policy Suggestions on Carbon Emission Reduction

Hubei Province is currently in its 12th Five-Year Plan development stage. Urbanization is accelerating and new industrialization is speeding up, which is sure to generate a relatively great demand on energy, increase energy consumption and consequently expedite carbon emission. Therefore, under the global trend of energy conservation and emission reduction, energy conservation and emission reduction should also be promoted in Hubei to go with the tide of history.

Develop and implement environment regulatory policies for different industries. To control carbon emission from different industrial spaces, laws and regulations and technical standards on carbon emission need to be set up and improved for related industries in an attempt to reduce carbon emission with the aids of law, policies and measures.

Optimize industrial structure to control carbon emission from industrial energy consumption. We can see from the above analyses that carbon emission from living and industrial-commercial space and transportation industrial space took up over 90% of the total carbon emission. Therefore, the energy-consuming secondary industry should be shrunk, while the tertiary industry, the high and new technology industry, and even the environmental protection industry should be properly expanded. To reduce carbon emission from the transportation industry, public transport can be further developed, and the efficiency of public transport should be raised.

TABLE 3 THE PROPORTIONS OF CARBON EMISSIONS FROM VARIOUS LAND USE TYPES IN TOTAL CARBON EMISSION FROM 2001-2011

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Agricultural space	0.04	0.03	0.03	0.03	0.03	0.04	0.05	0.05	0.05	0.05	0.06
Living and industrial-commercial space	0.87	0.87	0.81	0.83	0.81	0.81	0.80	0.78	0.80	0.81	0.80
Transportation industrial space	0.09	0.09	0.15	0.14	0.16	0.15	0.15	0.17	0.15	0.14	0.14

Exploit clean energy and enhance energy substitution. Further develop clean energies such as wind energy and solar energy so that they can be efficiently applied to industrial development and reduce fossil energy consumption by industries. As a result, reliance of economic development on fossil energy can be reduced and sustainable development of economic can be achieved.

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REFERENCES

He J, Liu B. Analysis of carbon emission intensity as the main index for greenhouse gas emission mitigation commitments. Journal of Tsinghua University (Science and Technology), 2004, 44(6): 740-743.

He Y, Li X, Li Q. Analysis on the effect of carbon emissions from different types of land use in Henan. Journal of Anhui Agricultural Science, 2012, 40(28): 14049-14051.

IPCC/OECD.IPCC guidelines for national greenhouse gas inventories[R]//Eggleston H S, Buendia L, Miwa K, et al. Prepared by the National Greenhouse Gas Inventories Programme. Japan, IGES, 2006.

Lai L. The effects of land use on carbon emission in China. PhD dissertation, Nanjing University, Nanjing, 2010.

Li P. Structure Optimization of Construction Land under Low Carbon Conditions: A Case Study of Jiangsu Province. Master thesis, Nanjing University. 2009.

Liu H, Liu W, Tang Z. The origin source and its elasticity analysis of the CO_2 emission induced by fossil fuel using industrial activities in China. Progress in Geography, 2010, 29(6): 670-676.

Lu F. An analysis on the relationship between energy consumption and economy growth in Hubei Province. Regional Economy, 2012, 9: 34-39.

Lu N. The effects of land use changes on carbon emission. PhD dissertation, Nanjing University, Nanjing, 2011.

Mohan K W, Fatih E , Tristram O, et al. Assess in terrestrial ecosystem sustainability: Usefulness of regional carbon and nitrogen models. Nature & Resources, 1999, 35(4): 21-33.

Qu F, Lu N, Feng S. Effects of land use change on carbon emissions. China Population, Resources and Environment. 2011, 21(10): 76-83.

Wang F, Wu L, Yang C. Driving factors for growth of carbon dioxide emissions during economic development in China. Economy Research, 2010, 2: 123-136.

Xiao H, Yuan X, Li B, Yan W. The effects of land use changes on carbon emission: Take Chongqing as an example. Journal of Chongqing Normal University (Natural Science), 2012, 29 (1): 38-42.

Zhao R, Huang X. Carbon emission and carbon footprint of different land use types based on energy consumption of Jiangsu Province. Geographical Research. 2010, 29(9): 1639-1649.

Zhao X, Zhu X, Zhou Y. Effects of land uses on carbon emissions and their spatial-temporal patterns in Hunan Province. Acta Scientiae Circumstantiae, 2013, 33(3): 941-949.